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Economizing as Exploring Valuations: How French Engineers Came to Valorize Telephone Calls

Alexandra Bidet

Abstract
This study deals with the building of a specific set of economic valuations throughout the work of French telephone engineers between 1880 and 1938. In so doing, it contributes to our understanding of the complex interplay between economization and valuation. Tracing the changing practices that facilitated a shift from valuation aimed at minimizing force losses to valuation aimed at assessing and enhancing subjective utility, economizing is considered as an epistemic process, through which managers, engineers and workers are exploring, representing and transforming the world. From saving work and minimizing losses to creating value, engineers went from evaluating (telling what is worth, within an economy of force, optimizing the ratio of losses over total work) to valorizing (framing value as possibly produced and not only saved, the production of utility). This new concern for valorization points to the development of new ideas on what could create economic value. In this process, the very acts of measuring, optimizing and calculating, appeared as both "subversive" and "subverted".

Keywords: economizing; metrics; inquiry; engineers; valuation; work; phone; value.

Introduction

This study deals with the building of a specific set of economic valuations throughout the work of French telephone engineers

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between 1880 and 1938. This was a pivotal period caught between the reign of the telegraph in the nineteenth century and the rise of digital technologies after World War II. In 1877, a number of French telegraph engineers were called upon to take up a very recent North American invention, still hardly in service on the other side of the Atlantic: the telephone. Consisting in the association of a transmitting microphone and a receiver, this technology initially seduced physicists because of its extreme sensitivity. Opening "a world of sound where we thought total silence reigned," it could detect low-intensity electric power, previously immeasurable "for lack of a yardstick small enough to allow comparison."[1] In the late 1870s, engineers working at the *Postes et Télégraphes* (the French national post and telegraph service) focused on two tasks: understanding the nature of telephone electric power and producing it with high-performance devices. Beyond the task of mastering problems of noise and distortion of sound came that of coping with the long series of innovations the telephone set had called for: transmitters and receivers, lines and their amplification, adaptation to many use contexts, newly discovered physical phenomena, mining and undersea exploration, military applications, musical broadcasting, network subscription, etc.

The two broad technological branches of the telephone (that is, transmission and switching techniques) relied on the same electromechanical basis. Electric power was used for transmission, and the electromagnetic properties of the relays were used to establish the connections (the movement of the mechanical parts being controlled by electromagnets). On the transmission side, the main issue was to compensate for the weakening of electric current with distance and to increase transmission capacities. On the switching side, the limits related to the time taken by switch operators and the volume of the mechanical components involved. The history of telecommunication technologies has focused on the distinctiveness of the 1878–1939 period: Griset (1991) contrasts the "revolution of electrical communications" with that of post-war electronics semiconductors, and Carré (1991) distinguishes a phase of networks expansion from a phase of acceleration of technical innovation and service growth. The interwar period stands between two techno-economic systems, but does also represent a foundational period for French telephone engineers.

In the interwar period, basic telephone services emerged through constant investigation of their value. What was valuable, what was useful about them? What deserved care and effort? What bore a cost? What was a phone call worth? What about the worth of the work of the operator connecting two callers? Such questions were recurrently

[1] "Du téléphone et des phénomènes physiques qui s'y rattachent," excerpt from a text by W. H. Preece (*Philosophical Magazine*), translated in the *Annales des Postes et Télégraphes* in 1878.

raised among telephone engineers. Yet these were not given a straightforward answer stemming from the gradual discovery of an already given value (Dewey 1939). The telephone was often considered as a rare, expensive, useless gadget for the rich. The French State had bought telephone networks in 1889, but these were not granted any real economic role (see Appendix 1). Until more recent, state-led development programmes in the 1970s, the telephone remained an infrequent product in France. Before World War II, subscribers were mostly business persons, and telephone networks were at first lines connecting households to factories. In 1925, more than half of the 25,000 networks in France still had fewer than five subscribers. Until the 1960s, the telephone was a matter of unconnected point-to-point lines and a myriad of small, local and unconnected networks. One had to wait until 1974 to see the rate of household equipment rise from 23 per cent to 90 per cent in ten years. In the three years 1974–77, then again in the two years 1977–79, as many lines were built as in the previous century. Before the end of the 1960s, the French State was not really interested in the telephone nor did it finance it. The telephone's frivolous pointlessness was aptly rendered in literary work, as in Colette's 1943 *Gigi*, where the telephone was said to be "only truly useful for men who make big deals or women who have something to hide." Notions of information theory ("information" as such, but also "performance") only began to be formulated in the 1950s. Before Claude Shannon, the telephone's only value was in the "messages" it transmitted, not in their informational shape and content. And the very concept of "message" obscured the telephone's advantage over the telegraph: namely, that of being put in direct communication and having an immediate response, if not a conversation.

Yet, at the same time, French State telephone engineers had undertaken elaborate economic valuations. Paying attention to measurement practices and cognitive artefacts (Pezet 2009), we can see economic valuations emerging from the daily work of these engineers. It is part of their job to reduce complexity and to accommodate recalcitrant phenomena by delineating inputs and outputs, expenses and effects, and by creating metrics to render them commensurable. Engineers enter a "cycle of measurement failure and reform" (Kurunmäki et al. 2016). To analyse this cycle, I draw on these state engineers' professional journal: the *Annales Télégraphiques*, from 1855 to 1899, and the *Annales des Postes, Télégraphes et Téléphones*, from 1910 to 1939. I carried out an inventory of reviews, reports and didactic articles. In 1910, the new edition of the journal aimed to enable engineers to "keep abreast of the improvements made in France and abroad to the branches of services in which they are interested" and to disseminate “the essential methods and general knowledge taught at the École Supérieure des Postes et Télégraphes,” where all engineers came from and sometimes taught at. Altogether, I examined and classified nearly 200 articles from the “phones” section published between 1910 and 1938.

French State telephone engineers did not write about economics or the economy.[2] Late nineteenth- and early twentieth-century telephone engineers had almost no knowledge of academic economics, and their writings made no reference to authors in political economy. Very little economic justification backed the 1889 state monopolization of phone companies. “While the mechanism of price elasticity was mentioned frequently, we find only a few traces of such thinking in the notions of networks and economy of scale,” notes Leroux (1991). Yet the idea was quite present for engineer Jules Dupuit, who justified the argument for nationalizing all networked businesses with the principle of the “natural monopoly,” which corresponds to the idea of an economy of scale: when the productive system is such that efficiency increases with size, the market “naturally” moves toward the construction of a monopoly (Vatin 2002). This does not prevent engineers, when the opportunity arises, from calling for the construction of a “satisfactory telephone service that the public rightly requests as an indispensable tool for national development and a necessary weapon in the industrial, commercial, and agricultural competition between nations.”[3] But they would not be heard until the 1960s. On the one hand, the telephone as a mode of transportation for sound was for long viewed as distinct from the idea of networked operations. On the other hand, tertiary activities, at the time, were devalued relative to primary or secondary activities, and messages could only be stand-ins, not real economic goods – as opposed to “information” today.

My focus here is not on marketizing but on quantifying and economizing (Kurunmaki et al. 2016). By showing how engineers work outside the market and shape the way in which technical devices are valued, I connect economic sociology with science and technology studies’ older focus on the social construction of technological artefacts (Bijker 1989; Callon 1998). This reveals STS’s “technological turn” towards the material reality of calculation as an even greater resource for economic sociology: not only has it long helped us understand how models, market devices and other material artefacts constitute and shape market behaviour, but it is also key to

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[2] I did not find any reference to economists in their productions, a course in political economy was nevertheless part of the curriculum from 1888 onwards at the École Supérieure des Postes et Telegraphes For the 1970s, see Bidet, 2010.

[3] “Le téléphone en France et à l’étranger. Progrès technique, organisation rationnelle,” *Annales des Postes, Télégraphes et Téléphones*, 1923.

understanding the broader making of economic valuations and their metamorphosis, which also involves the formation of new objects of measurement. Moving attention from "calculating economic life" to "governing economic life," Miller assumes that "the concern with practices has achieved a much wider sociological significance" (2008). Yet, in this article I do not seek to reduce "epistemic culture" (Knorr-Cetina 2007 [1997]) to modes of power: measuring can be about managing conduct, just as it can be about exploring and disclosing the world. My aim is to show how French State engineers came to transform and value the telephone as more than an expensive device for physicists, and to unpack the role that metrics played in this process.

Economic valuations were there from the start and (re)produced, along with new devices and new horizons of seeing and doing, representing and intervening (Hacking 1983). Engineers are continually engaged in such inquiries (Section 1). But inquiring on the telephone provoked a shift in focus towards economic valuations: the practical genesis of an idea *producing value (valorization)*. The understanding of how a valuable effect is shifted from minimizing force losses to producing subjective utility. The first valuation frame relied on an economy of forces, valuing the "smallest loss": engineers mostly counted losses to reduce them (Section 2). The second frame values the production of utility: engineers invent an economy of the "greatest gain" (Section 3) that eventually considers the telephone call itself as *producing value*. Thus the telephone is not only evaluated (granted a value) but also valorized (viewed as producing value).[4] This valorization deepens when engineers envision a law of demand stimulated by rising traffic and start framing users as customers (Section 4). Following this dynamic of changing valuations, I see engineers as paying attention to telephone lines, operators, circuits or traffic (Bidet 2005a; see also Appendix 1 and 2). But this logical succession does not imply a strict chronological order, nor does it delineate phases in the history of telecommunications: various foci can coexist in the same period, or in the same article in the *Annales des Postes, Télégraphes et Téléphones*. However, the broader shift towards a valorized telephone is manifested by changing concerns about metrics, interventions and values. Moving from an economy of forces towards the production of utility, the understanding of how worth is shifted from work value to utility value: whereas the first one could only be spared, the second one could also be produced.

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[4] On this distinction between evaluation and valorization drawing on Dewey's theory of valuation, see Vatin 2013.

Metrics: studying economic valuations within work practices

Measurement, especially the development of metrics, is a normative and highly creative process. François Dagognet has highlighted its unifying and revelatory powers (1993). On the one hand, things are no longer autonomous once they have been measured, but are assigned to a homogeneous group of commensurately valued things that makes them prone to automatic processes of connection: incommensurables become commensurables. On the other hand, measurement frees things from the relationships we form with them, allowing us to seize and manipulate them in new ways. They open new avenues for action, as they "discard the useless, the encumbering," and project the measured thing "onto a substrate favourable to an operational language" (Dagognet 1993: 167). Measurement produces new entities and opens up unexpected or recalcitrant phenomena for investigation. This process is "involved in the cumulative growth of systematic knowledge" intrinsic to the logic of writing (Goody 1977: 150), which begins with taxonomy and the making of lists and tables (Bowker and Star 1999).

Metrics are bound to performativity issues, but also to dynamics of inquiry, which do not point only to the pursuit of objectivity (Porter 1995) but also to the continued transformation of the world. Representing and intervening through metrics transforms phone calls and telephone entities within the process. Applying any metric to optimizing service leads to a need for new valuations. Inquiry is therefore a two-phase process. Defined as "the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole" (Dewey 1938: 108), it includes both phases of doubt and phases of certainty or knowledge. Telephone engineers move between moments of inquiry, seeking and inventing metrics to grasp and define new phenomena, and moments of optimization, when they know what to count and how to measure it. Models guide their choices in the latter phase, whereas they search for ways to accommodate and measure new entities in the former. The analogy of life that is so common in the engineering literature at the time grants these entities a natural economy, calling for endless exploration since all natural organisms keep changing. The metaphor of life is explicit: engineers are seeking iconographic reductions of the "telephonic life."[5] In telephonic lines, circuits or other items, they see "mechanisms that, by their flexibility and the endless number of accumulating combinations they allow,

[5] Here and below, the quotation marks indicate a frequent expression.

become almost comparable to living organisms, and like them are in a permanent state of evolution."[6] This pattern sustains the engineers' quest for iconographic reductions, their multiple attempts to crystallize the "telephonic life" in a curve, number, table or other visualizations. They want to see it "at a glance," as in the image of the effect that a spoken word has on the current in Figure 1.

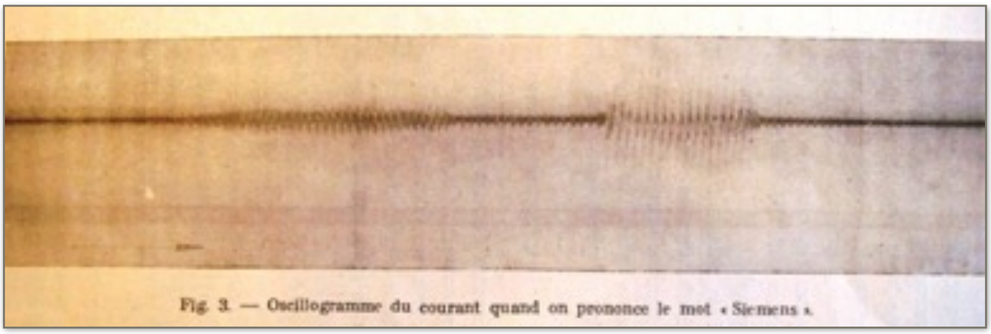

Figure 1. The primitive inscription of sound: the inscription foreshadows the ordering of a still-elusive phenomenon (caption reads "Oscillogram of the current when the word 'Siemens' is spoken").

The successive methods engineers invented for defining what should be sought and what makes the telephone valuable are part of its metamorphoses. Inventing a metric[7] is determining a frame which defines and prioritizes the various telephonic entities in a certain way, states their respective normativity (what they are worth, what they can claim or demand),[8] and requires that all choices be formulated within its optimization framework. To paraphrase Porter (1995), within each frame, engineers "trust in numbers," but between two frames they trust in experimentation, experienced judgment, and trial and error: their focus is less on accuracy than on the new phenomenon to be tackled.

A reminder of a few facts on early telephone technology: in the early days of the telephone, the voice was transmitted by an electric current running on a line. To improve this transmission, the focus was

[6] "L'autonomie financière des PTT et les méthodes modernes de comptabilité," (by E. Julhiet, engineer from the École Nationale Supérieure des Mines de Paris), *Annales des Postes, Télégraphes et Téléphones*, 1925.

[7] In his "plan for a sociology of measurement," Jean-Yves Trépos (1998) had already called for wide acceptance of the concept of measurement, including all the cognitive operations linked to commensuration processes.

[8] The term "normative entities" highlights the legislative dimension of the activities of the humans and non-humans involved in the operation of a technical set (Dodier 1995).

at first on the transmitter in the phone handset: it had to be strong enough to overcome the line's "resistance." The telephone lines themselves were initially so neglected that an adage stated "anything's good enough for telephone lines." But this focus no longer worked when instances of "strong" yet inaudible telephone signals arose.[9] The growing heterogeneity of telephone amenities and the invention of amplifiers (to increase the signal's strength) indeed entailed unexpected sound quality problems. Although electrical metrics were still envisaged at the first International Conference of Technicians of Telegraph and Telephone Administrations in 1910, a new measure, "conversation trials," would eventually replace them. This auditory measurement, based on comparison between equivalent lengths in "standard line meters," consolidated a variety of electrical properties into a single dimension: *attenuation*.[10] "Listening quality" was then calculated by measuring the attenuation each component introduced along the chain of connections between two speakers, from the telephone cord to the telephone exchange. But the goal and metric remained the same: avoiding *unnecessary* friction that would dissipate energy along the lines. Engineers were then committed to minimizing this energy loss. This valuation frame, very common to nineteenth- and early twentieth-century engineers, can be described in terms of an "economy of force" (Grall 2003). It is imbued with the same notions that came later to be systematized under scientific management: both draw from knowledge in industrial mechanics. This "industrial science" was developed by applying to machinery the twin concepts of effort and product that were borrowed from an engineer's observation of human work. This interplay between human work and machine work, and back, has been discussed by Vatin (1993).

An initial frame for valuation: saving work

Developing industrial mechanics, in the 1820s French engineers conceptualized the *work* of machines by analogy with human *work*: as both an effort and a product. In this conceptualization, "work" stood as a "mechanical currency" (Vatin 1993: 58): a common metric and what had to be conserved. As François Vatin demonstrated, this physicists' formalization of work has an economic connotation from the outset. The initial formulation of the physical concept of work by Gaspard-Gustave de Coriolis promoted the aim of a useful effect and

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[9] This ambiguity is specific to the physics of the era, which was preoccupied with the conservation of energy, while telecommunications techniques relied on the conservation of *variations* of energy.

[10] Meaning the relative decrease in the power of a signal during its transmission, it is the ratio between the effective value of the signal at the output and that at the input of the section under consideration.

an economic norm – the perfect transmission of work, without losses (heat, friction, waste, etc.): "[T]he faculty of working is limited for each time, for each place; it is not created at will. Machines only use and save work, without being able to increase it. Hence the faculty of working is sold, bought, and saved, like all useful things which are not in extreme abundance." On the one hand, the distinction between "lost" work and "usefully" used work is entirely subordinated to the economic purpose that is attributed to the mechanical device. On the other hand, the consideration of scarcity and opportunity cost appears to be at the heart of this optimization framework. Let us quote Coriolis himself: industrial mechanics elevate work – rare, since it tends to be lost – into a "mechanical currency" (according to the formula of the physicist Claude-Louis Navier), and it subsumes it to the principle of economic valuation.

This metric, by setting the perfect transmission of energy in machines as an economic ideal, casts mechanical phenomena as *imperfect transformations,* always entailing a certain *ratio* of losses. Telephone engineers proved to be the first committed to this *economy of losses*: maximizing the *ratio* of useful work to total work. They first tried to minimize the loss of energy in the telephone set, and then along the telephone lines. The domestication of various "telephone effects," necessary for putting the device into use, began by focusing on the transmitter's "power": "Every person who had a telephone at his disposal looked for a way to increase the instrument's power."[11] We have already presented the initial leap that would then shift engineers from analysing telephonic currents to an auditory measurement of line quality. Early telephone service had heavy line infrastructure costs. The new focus led engineers to create a space for potential arbitration between the cost of the line and its listening quality. Losses along telephonic lines were not merely seen as part of a natural economy to be studied; once lines had been made commensurable, losses became a problem to be fixed: difficult to solve, but acted upon. In a market setting, this could mean exploring demand in order to choose the level of quality with the best profit-cost ratio. Instead, telephone engineers aimed for a service quality standard that was both acceptable to the public and budget-compatible, or, put in another way, gave a "good transmission" at a "minimal price." The valuation of a "good transmission" was then the first conception of a *product* in this domain, since economic *value* was equated with minimizing losses along the lines.

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[11] "Le téléphone. Extrait du rapport de la commission spéciale chargée de l'étude du téléphone et des services qu'il peut rendre à l'exploitation télégraphique," *Annales des Postes, Télégraphes et Téléphones*, 1878.

Beyond optimizing telephone sets and telephone lines, this "economy of force" was also applied to the work of operators – the phone ladies (Bidet 2005b). As with the lines, engineers tried to establish a proportional relationship between the work to be done and the required workforce, with the aim to save work: "all shortening of the time needed for the establishment and even the termination of calls is a gain."[12] Concern for rationally organizing operators' work thus connected optimal productivity to the suppression of "useless movements and words" – those of the operators, but also those of the callers. The criteria of value were thereby related to the facilitation of service – with a focus on minimizing amounts of work. Thus, although the duration of communications was identified as a source of costs, it was not intended to provide a market response by charging for duration of communications. The primacy of a mechanistic framing of value over a market-based conception of cost is attested more generally by the systematic translation of the phenomena of congestion into a queue and into "dissatisfaction of the customers," but not in terms of a possible loss of profit. Duration was seen as a "useless" cost, and all the more so that it was not taken into account for the billing of long-distance calls, which was according to distance only.

From minimizing losses to *creating* value: shifting valuations

The development of the first intercity lines in underground cables, called "circuits,"[13] resulted from this continued search for minimizing losses along lines. But it also got engineers back into studying what to value, and how. Processes of valuation involve "exploring sites of dissonance" (Stark 2009; Berthoin Antal et al. 2015). Why did intercity operations upset the existing optimizing framework? Because new entities had popped up in the telephone landscape: "the length of auxiliary lines is no longer negligible," and "the scale of traffic between two localities does not justify the application of urban operation methods."[14] In other words, the cost of long circuits – the amortization of a "considerable immobilized capital" – prohibited their proliferation which would have offered callers a "chance of over 999 in 1000" to find one open.

[12] Henri Milon, *La téléphonie automatique,* Gauthier-Villars, Paris, 1914. An engineer, he was in charge of the Telephone Operations Service (*Direction de l'exploitation téléphonique*, created in 1909) throughout the 1920s.

[13] The first French intercity connection (1885) ran between Paris, Rouen and Le Havre. By 1890 there were 11 intercity lines in France.

[14] Henri Milon, *Principes généraux d'exploitation téléphonique*, 1925.

A "long circuit" then came to be defined by the need to update the criteria and methods for evaluation, and not by its length. Within a set distance of 100 kilometres, engineers kept their valuation frame: "the main point is not avoiding the loss of time, but the cost of labour."[15] But beyond 100 kilometres, they decided to focus less on speeding up the phone ladies, than on increasing the circuit's use. Here work – still measured by time – changed sides. Instead of referring to the work of connecting two lines, the "cost of labour" now referred to the work of building circuits, meaning that the same economic norm – minimizing losses – shifted from operators to circuits. Thereafter operators only had "a very small number of circuits to service": to facilitate "the increase of yield that the operator may obtain thus compensating, and more than compensating for, the supplementary personnel and equipment costs." It is not formalized theory, but practical knowledge "that allows this determination by trial and error."[16] In 1910, experiments were conducted on the six circuits connecting Paris to Lille: the challenge was to reduce the number of circuits assigned to each operator at busy periods in order to increase the average number of calls per circuit, so long as "the gain in receipts" remained higher than the increase in personnel costs. The number of circuits per operator was not determined by the average time taken to establish a communication link, but by the circuit's productivity according to its workload: "the supplementary operational charges resulting from it are minimal compared to the lack of gain brought about by a defective service."[17]

Let us see now how this management of intercity lines freed engineers from thinking solely in terms of losses. According to Latour, a valuation frame evolves when applied to "another regime of inscriptions and traces" (Latour 1985: 15). Figure 2 traces the duration of conversations on each circuit. In this figure, each horizontal line represents the duration for which a line was occupied; each line corresponds to a call, with a number indicating its chronological order. The interval between two vertical lines represents five minutes. One can see empty spaces between two consecutives black lines. Trying to

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[15] "La préparation télégraphique des communications téléphoniques et le rendement des grands circuits interurbains." *Annales des Postes, Télégraphes et Téléphones*, 1926.

[16] In the absence of graphic representation or formulae, the optimum balancing cost and a marginal gain remains implicit. "Moyens d'augmenter le rendement financier des grandes lignes téléphoniques," *Annales des Postes, Télégraphes et Téléphones*, 1922.

[17] "Le rendement des lignes téléphoniques en Allemagne," *Annales des Postes, Télégraphes et Téléphones*, 1913.

fill this space meant discovering a shortfall: engineers became *de facto* committed to get more instead of less. Of course, losses and gains are two sides of the same coin, but the concrete effort of the engineers shifted towards value to be created, and not only what could be saved.

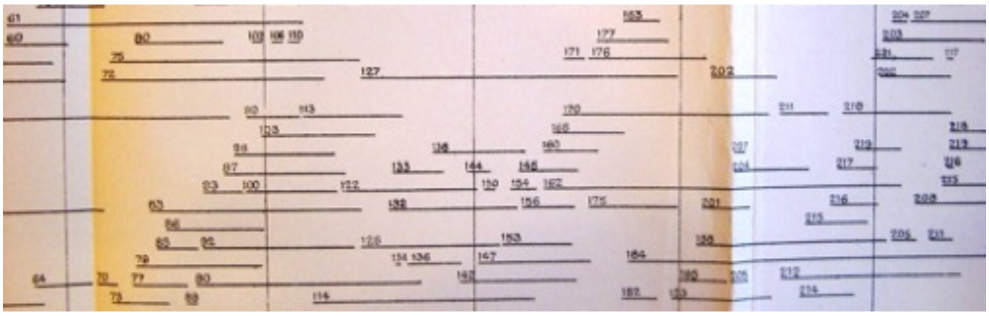

Figure 2. Detail. Graphic recording of the durations that lines in a group of auxiliary lines were occupied (reproduction of a 1918 AT&T document in the Annales des Postes, Télégraphes et Téléphones, 1921).[18]

The materiality of this managerial artefact makes it particularly effective (Bayart 1995), naturalizing a certain number of choices. The graph exposes an implicit valuation of circuits: successive calls were initiated one after the other and handled by a single operator. Put differently, calls were not addressed at the moment of demand. To improve availability, so that operators could increase circuit yields, they needed several pending calls lined up while they waited for an opening. Yet demand for calls only had these properties because of the reigning operational mode, and more specifically its particular constraint, waiting time, which regularly lasted several hours for intercity lines in the 1920s. We can see how a new object of optimization appeared from this observed fact: “the average waiting time depends on the excess demand which may occur at a given period on the circuits’ flow capacity.” There was consequently a need to “call back” people wishing to place a call and “take note” of their requests to establish a “chronological order” for the waiting list *(ibid.)*. Engineers went on to make this so-called “technical constraint” into an object of optimization, and thus management. Subjected to explicit organizational work, the *average waiting time* became a norm, maximizing the value produced by filling circuits based on the management and measurability of the calls on the waiting list.

Circuit yield thus illustrates the *practical* origins of what came to be valued and optimized, which emerged from *exploring* telephonic activity’s constraints and components. From this perspective, it is not constraints as such that are interesting for engineers, but their

[18] “Mission de fonctionnaires des Postes et Télégraphes aux États-Unis,” *Annales des Postes, Télégraphes et Téléphones*, 1921.

potential link with a product, their potential effects, and the correlate possibility of deriving optimization from their exploitation. In turn, in this optimization the technical "data" stand as pre-existing constraints, no longer suffered *ex post* but posed *ex ante*. Turning necessity into a virtue is thus the hallmark of an inquiry grounded in practice. The service came to rely on the possibility of calculating waiting times, which dictated the operators' load as well as indicating *a probable waiting time* to the callers.

In Figure 2, we can see an unexpected consequence of this new metric: all the conversations are short, rarely filling (and never exceeding) the space between two vertical lines – that is, five minutes. This is the result of operators' work ensuring that the standard call duration of six minutes was respected and "cutting" conversations when other callers were waiting. Without this *standard conversation length*, any "indication of the probable waiting time would be illusory": the average waiting time would not be calculable in advance. Engineers' new valuation frame thus required operators to "[*cut*] conversations off." Operators also saw the paradox of such an optimizing method that involved "cutting" calls: "this condition is not favourable to yields, because the more a subscriber talks at length on a circuit, the better the circuit is occupied."

This choice was adopted partly because it was nearly impossible to object to it at the time: calls were considered simple exchanges of messages, with no value attached to their duration.[19] In addition, long calls went against the principle of *public order,* born of an economy of penury: "from a general point of view, it is impossible to let a subscriber monopolize a circuit over a certain time; the limitation [*of conversation length*] allows for the satisfaction of the largest number of subscribers and avoidance of excessive displeasure for the clientele."

Consequently, with pricing remaining per unit,[20] "cutting" calls made the rate correspond to the *duration* a circuit was occupied, in turn making it profitable to optimize circuit use. Establishing a rate or an operating mode always has unintended effects – externalities. As Callon's "overflowing mechanisms" (1998) revealed, all framing, being

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19 Duration is introduced in France only in 1985 in the billing of local calls.

20 The unitary fee ("taxed conversations") replaced the flat-rate subscription from 1924 onwards in France. The flat rate subscription was supposed to cover an average use and understood as the price of access to the service. Until 1924 it allowed an unlimited number of conversations within the local network. However, the rationality of unitary taxation was unquestionable for engineers: a rational price should cover the cost price, identified then with the direct human work of putting callers into conversation. But the cost of counting calls was hitherto an obstacle to the unitary fee.

imperfect and incomplete by definition, is also "its own inescapable source of the threat of overflows" (Çalışkan and Callon 2009, 2010: 8). Here we see the relationship between metrics and valuations: a metric, being the product of a way of assessing value and cost, when established, brings to the fore new entities that may create dissonance and require new valuations. Although in this case it was initially cost that justified the revenue (rare and expensive circuits should "pay"), the rationalization of their use shifted engineers' thinking to "gain." And with the change in billing practices for calls over 100 km, long-distance calls started to "pay," contributing to the gradual disappearance of competing costs from equations. As the "revenue depends on the number of calls made,"[21] the extent of the use of circuits, especially "some big circuits with a lot of traffic" and a high per-unit rate, became subject to "minute by minute" attention, so "that the conversations follow each other almost without interruption" to "increase the lines' income" and "the circuits' paid occupied time."[22] In thinking of the rate as the remuneration of capital investment, engineers opened a new field of monetary *ratios*.[23] Their analyses began to dissociate usefulness from a *modulation of the useless*: "productive minutes" are distinct from "lost minutes" *by nature*. Monetary valuations then went on to give weight to this new figure of created gain or value. They increased and highlighted the specificity of "productive minutes": they "pay." Those operating the nascent system thus came to associate the circuits with the production of utility and revenue which would increase with the duration of the calls, and in doing so also the service's worth increased.

This process does not mean the emergence of a commercial focus, however. Making an issue of "financial yield" did not lead engineers to anticipate a *commercial* response to telephony's condition of chronic penury. The possibility was nonetheless raised as early as 1887, in the *Annales des Postes, Télégraphes et Téléphones*' first contribution to intercity telephony, when an engineer, echoing a debate over a rate change opposed by railway engineers, set out to dissipate the "mirage" of a low fee. Only a high fee could chase "off the callers who only have an insignificant reason to place a call, [*and*] would allow the acquisition of regular service" that would be favourable for "truly

[21] "Méthode d'exploitation des lignes téléphoniques interurbaines," *Annales des Postes, Télégraphes et Téléphones*, 1916.

[22] *Ibid.*; and "La contribution des ingénieurs français à la téléphonie à grande distance par câbles souterrains," *Annales des Postes, Télégraphes et Téléphones*, 1917.

[23] The 1923 accounting and budgetary reform instituted amortization and introduced a distinction between the establishment's costs and income and those of its operations.

commercial usage."[24] The French economist-engineer Jules Dupuit inspired this rationale: since a call is not worth the same to all agents, fixing a price level selects those for whom calls are worth the given value. But this interpretation of Dupuit is paradoxical; the problem he presented was not, in fact, resource scarcity, but a desire to set differential rates so everyone would have access to a good at a price each could afford. On the contrary, as the quote shows, future price would determine the corresponding demand, since the supply is fixed. Resource distribution could thus be adjusted by price, not by waiting list. [25]

The development of a commercial rhetoric (clientele, income, profits and so on) supporting the valuation of circuits was more a reflection of the extent to which engineers (who trust in numbers) valued *calculation* itself than an indication of a commercial turn. Calculation and optimization were their standard routine, radically different from the "search for numbers" they returned to periodically when reaching the limits of a model or a metric that failed to contain its overflow. In this case, calculation has more to do with the "thought's tendency to rest"[26] than with the drive for gain or love of knowledge.

In this shift from evaluation to valorization, from value as being saved to value as being produced, engineers' valuation of circuits also led them to discover a "law of demand" and to value "clients."

Discovering a law of demand

This progressive shift in valuation frames was not led by a broader rationale guiding the development of telephone services (not envisioned as an economic tool until the 1960s) by the French State nor by technological changes. Valuations and techno-organizational changes were integral to the same mundane dynamic of inquiry. When inquiring, engineers modified simultaneously their valuations and their

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[24] The perspective is dynamic; receipts should allow new lines to be financed, which would then allow rates to be progressively lowered, which was "increasingly practical, because the multiplication of needs will be preceded by the multiplication of means for action."

[25] This system only works with one of the two dimensions of Dupuit's variation of utility: the hierarchy of needs, not the wealth pyramid.

[26] We know that Charles Sanders Peirce (1978) described this research as an attempt to escape the irritation of doubt, and to re-establish a state of belief within a "community of competent explorers."

environment (organization, technology, etc.).[27] And as they modified their environment, they were more likely to get back to inquiring again as new entities and unexpected side effects emerged. Maximizing circuit yield put engineers face to face with an unexpected observation: "The measurement [*of consequences from the increase in operators*] also highlighted a frequently observed economic phenomenon: since calls were connected more reliably with shorter waits, *demand grew,* and the daily average once again rose rapidly."[28] This was a side effect of the previous optimization, which created relative abundance after a phase of managing cost. As a result, engineers noticed that "putting a new line into service" prompted "an increase in traffic."[29] Such observations suggested the existence of a predictable and potentially valuable demand, not just a "nuisance." Financial objections to the development of underground cables could thus be mitigated:

> The sound is still good, and one can rely on calls that have been put through. The absence of parasite noise is so complete that understanding is greatly facilitated. Public confidence is increased, which leads to *a more frequent use* of the telephone, which greatly improves circuit use, and with that, receipts. It soon becomes necessary to use the reserve circuits, and the time they spend unused is of short duration. [30]

As a result, the valuation frame's specific operational mode focusing on circuit yield became obsolete. When aerial lines were replaced with underground multi-conductor cables, waiting times shortened and operators no longer needed to constantly prepare circuits to assure supply for a waiting list of pending calls. In losing its relevance, the previous valuation of circuits lost its performativity:

> It is illogical to impose an avoidable waiting time on the clientele with the sole aim of increasing the yields on the circuits in service, since alongside them there are also circuits with zero yield for which the amortization fees and upkeep are, with very few exceptions, equivalent.[31]

The expression "it is illogical" marks the effort needed to break free from an existing frame: what was once logical ceases to be so *when the frame is no longer relevant*. But the fact remains that with an

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[27] For more on this, see Bidet (2014), Bidet and Vatin (2008), as well as Schön (1983) and Bayart (2000).

[28] "Moyens d'augmenter le rendement financier des grandes lignes téléphoniques," *Annales des Postes, Télégraphes et Téléphones,* 1922 (emphasis added).

[29] "Le rendement des lignes téléphoniques en Allemagne," 1913.

[30] "Les lignes téléphoniques souterraines interurbaines," *Annales des Postes, Télégraphes et Téléphones*, 1916 (emphasis added).

[31] "Les nouvelles méthodes d'exploitation interurbaine. Le trafic direct," *Annales des Postes, Télégraphes et Téléphones*, 1930 (emphasis added).

abundance of circuits, their productivity "no longer [*has*] an appreciable influence on the amount of receipts, since no demand is at risk of cancelation because the lines are encumbered."

Since the drastically shortened waiting times made it impossible to anticipate a longer waiting list, engineers went on to build a new *optimum* corresponding to the vanishing waiting lists: "operational methods should, then, not only increase the circuits' yield, but reduce the waiting time in a more satisfactory way for the clientele and increase the number of demands."[32] The aim is no longer a stable "maximum yield" optimum, but dynamic growth in circuit yield due to increased *traffic*, which becomes the new variable to maximize. In the early 1930s, this preliminary intuition of a "law of demand" sparked the development of an operating mode called "direct traffic," modelled on American "no-relay service."[33]

Discrete management (call-by-call) was thus followed by continuous management (of flux): *traffic* no longer designated a given constraint to be coped with, but a *variable at hand to be optimized*. The service's worth was no longer set in *evaluating* the cost of operators' labour but in *valorizing* the "demand" for phone calls by increasing it. Its emergence as a central issue piqued engineers' interest in the behaviour and satisfaction of *those using the service*. Mastering traffic flow henceforth meant taking account of the public's learning curve, anticipating the consequences of growing "confidence" in the service, "the habit of being served rapidly," being able to hear well and so on. Advocates for the "receipts angle," then, did not merely appeal to subscribers for legitimacy; a "client" rendered measurable was needed to run their calculations.

Conclusion

Economic sociology has paid little attention to economic valuations beyond prices, as prices have long seemed to be the metrological index for value. Many sociologists, like Jens Beckert and Patrik Aspers (2011), continue to share with economists the postulate that sees the central place of revelation and/or formation of economic value in the marketplace. This study sought to illustrate another approach to the study of economic value. It avoided the aporias of the noun "value" by preferring the verb "to value" (Dewey 1939), which encourages us to describe *acts* of valuations: activities, practices, processes that value a

32 Ibid.

33 Ibid.

situation, an object, an event, a person or a way of doing things. Economic valuation, from this perspective, finds a broader meaning. Economizing is not limited to "framing" activities around the exchange, nor to "the ideas and instruments through which individuals, activities, organizations, nation states, regions, projects, and much else besides are constituted as economic actors and entities" (Kurunmäki et al. 2016: 395). Beyond market orientation *stricto sensu*, lies the mere interest in optimization. At the root of the notion of economy, we indeed find the act of management (Vatin 2008a, 2008b), that is to say, the relation of an action and its effects, that one can assess according to various criteria, various metrics. To inquire into economic valuations, we shall then also look within organizations, companies and work practices – these "black boxes" of economic theory (Bidet 2011, Favereau et al. 2016). Any place devoted to work and management is full of inquiries and standpoints, often of a performative nature, on how to produce useful effects.

To track these economic valuations, a metrological approach proves relevant. The issue of measurement does not only give here an analytical status to organizations, businesses, companies in economic sociology. It also asks us to consider these organizations through their concrete work activities. What is valuable? All actors at work are confronted with this issue. Explicitly or implicitly, they use, explore and create metrics aimed at valuation. Paying attention to these metrics that inhabit practices and devices deploys a new perspective on economizing. Let me emphasize two specificities. A first point is that, contrary to Michel Callon and Bruno Latour (1997), who were mostly interested in the moving partition between what counts and what does not count, the inside and outside of calculations, the commensurable and the incommensurable, as two complementary framings, I consider the very process of doing commensuration: how to count, and to make disparate elements commensurate? Especially: what to put in the denominator and the numerator? What should be considered as a product, as a cost, etc.? In this process, calculation and judgement do not draw distinct worlds. The very possibility of measurement, of calculation involves setting standards of value (Barraud et al. 2013; Bidet and Vatin 2013). The second point is that, contrary to many inspiring studies in accounting and management science, which have studied management and work practices for a long time, I emphasize the epistemic dimension of work: besides the classic problem of control or governing – the conformation of behaviours to norms – I also consider economizing as an epistemic process, through which managers, engineers and workers are exploring, representing and transforming the world. It necessitates that they not only try to articulate pre-existing and dissonant conceptions of worth (Stark 2009); they also inquire into what is valuable and these inquiries lead them to create new metrics. They rework metrics already at work in society, and they contribute unintentionally to their shaping.

In this study, we saw during the interwar period French State phone engineers wondering whether phone lines or phone calls were only consuming value or if they could also create some. The latter idea appears gradually, through a dynamic of inquiries and shifting of economic valuations. From saving work and minimizing losses to creating value, engineers went from evaluating (telling what is worth, within an economy of force, optimizing the ratio of losses over total work) to valorizing (framing value as possibly produced and not only saved, the production of utility). This new concern for valorization in the phone industry points to the development of ideas on what could create economic value (and not only minimal losses or offset costs). In this process, the very acts of measuring, optimizing, calculating, appeared as both "subversive," in that they pushed those who conceive metrics to transform the phone organization, and "subverted," in that when they mobilize a metric they often also contribute to redefining and transforming it. Finally, studying economic valuations through metrics stresses an indefinite creation of commensurability. Thereby, economic sociologists have the opportunity to capture the creativity of social action – a dimension which the hegemony of the two rival models of rational action and normative action has long eclipsed.

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Appendix 1 Chronology

1792 The system of optical telegraphy invented by Chappe appears in France.

1820 Three physicists (Oersted, Ampère and Arago) develop the electromagnet: electricity can be used for communication.

1837 Law passed on the monopoly of telegraph lines. The American Samuel Morse invented the electrical telegraph: a simple code uses the variation of the pulse rhythm to convey a message.

1851 Opening of the electric telegraph to the public.

1855 Creation of the Telegraphic Annals.

1876 First telephone patents by Graham Bell and Elisha Gray in the United States: the vibrations communicated by the voice to the transmitter membrane cause a magnetic flux of a magnetic bar placed in front of it, causing electric currents induction.

1877 Arrival in France of the first prototypes of telephone. Invention of the microphone by the American Hughes.

1878 A first commercial telephone switchboard is put into service in Connecticut and serves 21 stations.

1879 The Postal and Telegraph (P&T) Administration authorizes the creation and operation of telephone networks. A first network is put into operation in Paris. The limit reached by the telephone tests is 150 km.

1880 Paris has 100 subscribers including 22 newspapers, 70 banks, stockbrokers, brokers. The three companies merge into the General Society of Telephones. It reorganizes the network of Paris and creates those of Bordeaux, Marseille, Nantes and Le Havre.

1881 The Société Générale des Téléphones (SGT) has fewer than 2,000 subscribers. Paris has seven central offices and more than 300 lines. Seven provincial cities have a network.

1882 Beginning of the expansion of the telephone in France. The first "annunciator" boards serving small inland networks appear. The Minister of P&T obtains from the chambers a credit to test the operation of the telephone.

1883 Opening of the first telephone networks managed by the state in Reims and Roubaix. Ministries and large enterprises develop indoor facilities.

1884 Almost all major cities in France are equipped with a telephone network. Renewal of the concession for five years of telephone networks. SGT ceases to invest in networking and benefits from its monopoly.

1885 Opening to the public of the first intercity link between Paris, Rouen and Le Havre. The rate for a 5-minute conversation is 3 francs (the average daily wage of a worker is 5 francs).

1887 SGT has 7,666 subscribers in 11 networks; the state, 1,627 subscribers in 11 networks and 16 networks in creation.

1888 France has more than 10,000 subscribers, including 6,000 in Paris.

1889 Creation of the first subsidiary budget (applied only for the budgetary years 1891 and 1892). Nationalization of the telephone networks of SGT, which has 9,100 subscribers. The P&T engineers are responsible for their management. They join the Ministry of Trade and Industry. The development of the telephone is entrusted to the municipalities via the process of "repayable advances". The development of urban networks accelerated between 1890 and 1893.

1890 In France there are 11 intercity lines. Invention in the United States of the first electromechanical switching system: the "Strowger".

1891 A decree extends the system of repayable advances to intercity lines. Plan to reorganize the Paris network (creation of the first subsidiary networks). First submarine telephone cable (Dover-Calais).

1892 France has 220 central offices (telephone exchanges). The first automatic one is put into service in the United States.

1895 The law modifies in part the powers of the telegraph engineers, henceforth guarantors of the interests of the state with regard to the global electrical installations and the protection of the telegraph and telephone lines.

1899 A. Millerand, the new minister in charge of P&T, launches a plan of economy. The publication of the *Telegraphic Annals* is stopped.

1900 Millerand report on the phone. France has 56,000 main subscribers. Responsibility for the development of telephony passes from the communes to the departments. Invention of the "Pupin" load coils to reduce the weakening of underground cables.

1902 Creation by A. Millerand of a state body for the engineers of P&T. It includes only 37 engineers until the end of World War I.

1904 First use of the notion of "telecommunications," by E. Estaunié in his *Traité de télécommunication électrique*.

1905 Establishment of the Association of Telephone Subscribers.

1906 Invention of the tube amplifier, the triode of Lee De Forest, the origin of all electronics. Beginning of substitution of multiples to standards. Huge strikes of operatives until 1909.

1909 Intense public debate on the crisis of the telephone and its financing. The newspaper of the association of subscribers titles article "Telephone anarchy". The Materials and Construction Department, occupied by E. Estaunié, becomes the "Telephone Operations Directorate". There are 44,600 subscribers in Paris. The telephone share takes precedence over that of the telegraph in the total number of calls.

1910 France has one subscriber per 200 inhabitants. Plan for census of the French telephone lines. Very great weakness of interdepartmental links. First issue of the *Annals of Posts, Telegraphs and Telephones*. The number of posts per 100 inhabitants is 0.5 in France, 1.3 in England, 1.5 in Germany, 3.1 in Sweden, 3.7 in Canada and 7.6 in the United States.

1913 Inauguration of the first automatic exchange (Strowger) in Nice. France has more than 22,000 exchanges and 340,000 subscribers, 65,000 in Paris; telephone density is 0.77. Creation of the Association of Postal and Telegraph Engineers.

1920 Report by H. Fayol on the "Industrial incapacity of the State and the Post Telegraph Telephone (PTT)". Launch of renovation of the network, under the supervision of A. Millerand (President of the Republic).

1921 France has 474,000 subscribers, one-third of these in Paris. Commissioning of an automatic exchange in Orléans.

1922 Project for automation of the Paris network. First PBX commissioned in New York. Paris has 120,000 subscribers.

1923 Vote on 30 June of a "subsidiary budget" of the PTT and a ten-year turnaround plan. The average waiting time for a long distance call is five hours.

1924 First telephone cable (Paris-Strasbourg). The unit charge progressively replaces the flat fee. Creation of the Underground Lines Service at long distances. Control of the first long-distance cable (Paris-Strasbourg). Standardization of subscriber stations (150 types were in service).

1925 Start of the French network of long-distance cables; of the 25,000 networks in France, more than half have fewer than five subscribers; Of the main lines, 4 per cent are served automatically. Beginning of use of tube amplifiers. Taxation per duration is generalized.

1928 The Paris network has 159,000 subscribers, serviced by 6,480 operators. Commencement of 21 automatic central offices in Paris. Ten switches have been installed in the provinces. The French telephone density is 2.2. France has twenty times more central exchanges than the United States for eight times fewer lines per capita. Creation in Paris of the first teams specialized in the maintenance of long distance cables. Permanent service is provided in all networks with more than 200 subscribers.

1930 The economic crisis is jeopardizing the financing of the recovery plan.

1931 The Paris network has 189,000 subscribers (including 82,000 automatic) and 5,600 operators.

1932 Of the main lines, 25 per cent are connected to automatic exchanges (this rate is 48 per cent in Paris). Nearly a quarter of the lines are concentrated in Paris. Out of 38,000 municipalities, there are 31,939 networks, 70 of which exceed 1,000 subscribers (average of 5.7 subscribers). First automatic zones are built around certain cities (Saint-Malo, Deauville).

1933 The first suburban switches are in operation in Paris.

1934 Cancellation of credits stops automation of the Paris network for 20 years.

1935 Use of the carrier current technique to transmit several communications on the same line. The inter-urban central office of Paris generalizes the operation with direct traffic to all its connections.

1936 Development of semi-automatic rural central offices. Installation of the first long-distance coaxial cables in the United States and Great Britain. Creation of telephone districts, grouping together the networks of a canton, and benefiting from a simple tax.

1938 Of the main lines 55 per cent are still served by manual exchanges (16 per cent in Germany). The telephone density is 2.4 stations per 100 inhabitants. France reaches a million subscribers. First automatic intercity link between Nice, Cannes and Monaco.

1945 Long distance calls are charged directly to the meter and not by ticket.

1947 France is the first country in Europe to establish a coaxial cable link over a distance of more than 800 km (Paris-Toulouse).

1948 Article by C. Shannon in the *Bell System Technical Journal*, founder of the theory of information. France has 5.8 posts per 100 inhabitants (compared with 9.3 in Great Britain and 24.2 in the United States).

1949 The American Von Neumann develops the first computer: the birth of computers is linked to the digitization of information.

1951 France is the first country in the world to set up an automatic long-distance link (500 km) from subscriber to subscriber (Paris-Lyon, 50 circuits).

1955 Of long distance traffic 15 per cent is fully automated.

1957 The rate of automation of the French telephone network is 55 per cent. Introduction of a reduced tariff in fully automated connections.

1960 Nine telephone sets per 100 inhabitants (compared with 15 in Great Britain and 39.5 in the United States).

1963 5.4 telephone lines per 100 inhabitants (27.6 in the United States, 9.7 in Great Britain).

1964 The connection time is on average 3 years.

1966 The Fifth Plan (1966–70) began a modernization of the network: telecommunications are recognized as a major infrastructure and a factor of economic development. The number of main subscriptions is fewer than 3 million.

1967 France has 400,000 pending connection requests.

1968	Rate of telephone equipment of French households was 15 per cent.
1970	Telephone density was 7.8 main lines per 100 inhabitants in France, 15.3 in Great Britain and 33.3 in the United States. In 1968, the rate of telephone equipment in French households was 15 per cent.
1971	The Sixth Plan highlights the role of telecommunications in French economic life. It has credits three times higher than the Fifth Plan and its first objective is "the smooth flow of traffic".
1973	The Sixth Plan becomes the "Telephone Plan". Direction Générale des Télécommunications (DGT) becomes the largest French public investor. The Paris network represents one-third of subscribers and revenues. Official establishment of the Operational Directorates. Removal of the quantum of connection in the taxation of communications by automatic means.
1974	France has 6 million subscribers. Of households 23 per cent are equipped.
1976	The Seventh Plan makes the telephone the subject of a priority action programme.
1978	In the year, more than 10,000 new subscribers are connected per day (compared with 100,000 per year in the 1950s).
1980	Of French households 80 per cent are equipped. They represent 80 per cent of the number of lines.
1983	The telephone density is 37.6 main lines per 100 inhabitants in France (41 in the United States, 35.8 in Great Britain, 38.3 in Germany).
1984	France has 22 million subscribers. Of households 90 per cent are equipped. Implementation of a four-tiered hourly rate modulation system.
1985	Implementation of new telephone numbering. Introduction of duration into the taxation of local communications.

Appendix 2 Synopsis of valuation frames

VALUATION FRAME	Infra-structure	Uses	Tests	Problems	Purposes	Optimized object	Measures	Metrics	Graphs	Focus of attention	Pricing criteria
ECONOMY OF FORCE (evaluation) applied to lines	Air phone lines	Domestic Local	Transmission of voice and current	Energy losses Attenuation Audition	Increase the work capacity of lines Reduce cost	**Energy**	Clarity and efficiency Audition	Standard line Transmission standard Ear	Electric graph Transmission graph	The request and voice of the subscriber	Prime cost of production Flat rate
applied to operators	Underground cables Urban switching	Shortage	Connecting caller and receiver	Unnecessary gestures Unnecessary words and call: abuses Call overload	Maximize work performance Minimize work expenses	**Human work**	Workload Operating time Service quality	Perfect efficiency of operators Equalization and standardization of work	Timer: time measurement Operations table Counting	A service to subscribers	Direct labour Unitary fee
PRODUCTION OF UTILITY (valorization) applied to circuits	Under-ground cables Intercity lines Mechanization: semi-automatic	Shortage	Monitoring of circuits load	Immobilization of circuits	Increasing the gains circuits Minimize expenses	**Circuit yields**	Circuit loads Law of call	Maximum efficiency of circuits	Table of level measures	Transmission capacities	Prime cost for production Circuits Unitary fee
applied to traffic	Direct traffic Automation Maintenance	Industrial	Traffic flow	Disturbances Traffic loss	Gain Maximum receipts	**Customers** **Traffic**	Traffic statistics	Constant traffic flow	Industrial accounting Probabilities	Connection capacities and subscriber behaviour	*Ad valorem*: subjective utility Price according to duration